All gone: Land use change, including deforestation, is one of the major human impacts on the Earth system that have triggered a departure from the conditions defining the Holocene epoch. (Photo: Aidenvironment, Wikimedia Commons.)

on the environment, including changes to land, atmosphere and oceans, but it was also the time when human activity became globalised. This led to a whole range of new global problems, from the destruction of atmospheric ozone through to accumulation of marine litter, climate change, ocean acidification, and more.

These global changes would already ensure that geologists of the future would find it relatively easy to spot the middle of the 20th century in any sediment layers. "One thing that has struck me is the way that a number of the activities and Earth process trends graphed by Will Steffen and his colleagues translate effectively into geology," remarks Zalasiewicz, "the carbon emissions are reflected in changes in carbon isotopes in plankton shells, the nitrogen shift is seen in the chemistry of lake layers, the biospheric changes will be reflected in future fossils, and so on. It's quite a neat interplay of action and petrifaction."

As a bonus feature, however, humanity left a foolproof geological signal that can be pinned down to a precise date, namely the first testing of an atomic bomb at Alamogordo, New Mexico, on July 16, 1945. The radionuclides from this nuclear explosion — and the ~500 others that followed until 1963 — spread around the world and can be easily identified in sediments and ice cores.

Choosing the first test as the beginning, rather than the peak of the testing craze in the 1950s, the authors argue, has the advantage of clarity, as all anthropogenic radionuclides found would automatically be counted as within the thus-defined Anthropocene. This suggestion, the authors emphasise, is not just a contribution to the ongoing consideration regarding formal approval of the Anthropocene as an epoch. It could be used even if it remained just an informal concept.

The working group aims to make its recommendation at the International Geological Congress in 2016. If it recommends the new epoch, a subcommission of the ICS will then take over and decide whether to submit a definitive proposal to the ICS for its epoch-making decision.

Whether or not the Anthropocene becomes a new epoch, the fact that we have already kicked the Earth system so hard that that it appears to have left the stable equilibrium of the Holocene should spur humanity into action. Considering the extreme climate swings and mass extinctions of the geological record, the Holocene was a surprisingly cosy epoch uniquely suitable for a nearly hairless ape species to colonise the whole world. Now that we are essentially driving the changes at the planetary level, we should do all we can to stay in the Holocene.

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Q & A

Stephen M. Kosslyn

Stephen M. Kosslyn is the Founding Dean of the Minerva Schools at the Keck Graduate Institute (one of the Claremont Colleges). He served as Director of the Center for Advanced Study in the Behavioral Sciences at Stanford University and was previously chair of the Department of Psychology, Dean of Social Science, and the John Lindsley Professor of Psychology at Harvard University. He was also Associate Psychologist in the Department of Neurology at the Massachusetts General Hospital and co-director of the Mind of the Market Lab at Harvard Business School. He received a B.A. from UCLA and a Ph.D. from Stanford University, both in psychology. Kosslyn has authored or coauthored 14 books and over 300 papers, for which he has received numerous honors, including the US National Academy of Sciences Initiatives in Research Award, a Guggenheim Fellowship, three honorary Doctorates (University of Caen, University of Paris Descartes, Bern University), and election to the American Academy of Arts and Sciences.

How did you get interested in biology? I didn't start out interested in biology. I backed into it in order to answer specific questions.

I went to the graduate school at Stanford University to study psychology. This was right at the time when Neisser's ground-breaking book *Cognitive Psychology* came out. This book led me to think of the mind by analogy to a computer program, which in turn led me to think about how humans store information in memory. I focused on one way in which information could be stored, as visual mental images.

Where does biology figure into this? A large part of my work on visual mental imagery was designed to discover whether visualizing with one's eyes closed recruits many of the same neural mechanisms as visual perception. This approach allowed my colleagues and me to address a fundamental question about visual mental imagery: does it make sense to think of visual mental images as 'mental pictures'? Obviously, they aren't real pictures — think of how uncomfortable it would be to have real pictures in your head, and besides… who or what would 'look' at them? More precisely, we asked whether mental images 'depict' information, as opposed to describe it. (By 'depict' I mean that each part of the representation corresponds to part of the represented object such that the distances among the parts of the representation correspond to the distances among the parts of the represented object itself.)

As it turns out, turning to the brain was a good way to begin to answer this question. Many of the visual areas of the brain physically depict shapes on cortex. The earliest areas in the processing sequence, such as area V1, are retinotopically mapped: the spatial layout of the retina maps neatly onto the surface of the cerebral cortex. My group, and now many others, showed that area V1 is activated during visual mental imagery, at least for many people, and that the pattern of activation in this area is similar to that found when people are actually seeing the stimuli (not merely visualizing it with their eyes closed). Moreover, when transcranial magnetic stimulation is used to impair the functioning of area V1, visual imagery and visual perception are impaired to comparable extents. These sorts of findings are strong evidence that visual mental imagery involves depictive representations.

Thus, biology has proven very useful for addressing the questions I had about internal representations in human memory. This convergence of psychology and biology is very exciting.

You recently joined a Silicon Valley startup — and not a biotech one, at that: why? My work on mental imagery became intimately tied to work on visual perception proper, and that in turn led to an interest in visual display design (for example, I've written two books on using psychological principles in graph design). I became increasingly interested in using what is known from laboratory studies to solve real-world problems. Such interests grew while I was dean of social science at Harvard. During that period, I became interested in the science of learning. A huge amount is known about memory, learning, motivation, and related topics — and very little of it has been used systematically in education. It turned out to be very difficult to induce faculty to use such information in their teaching.

My joining Minerva, and now heading the Minerva School of Art and Sciences at the Keck Graduate Institute (one of the Claremont Colleges), has provided a rare opportunity: We can use the science of learning systematically to help students to learn. We've 'pushed the reset button' for higher education, and are reconsidering every aspect of the university experience. It is stimulating beyond words to be able to use the science of learning in new ways in settings that can improve lives.

What is the best advice you've been given? When I was a graduate student, I worked very independently. At one point, I went to my advisor, Gordon H. Bower, and complained that half of my experiments were failing. He looked at me for a moment, and then said that I must be doing something wrong — at least two-thirds of them should be failing! He said that it was easy to ensure that the vast majority of experiments would work: just make them simple variants of previous experiments. But that would be a waste of time. He told me that what I should be doing was thinking about things from radical new angles, and conducting risky experiments that would tell us a lot if they worked. This proved to be excellent advice.

What has your relationship been like with your students? I typically treat them as apprentices for the first year or two, and then more like colleagues for the remaining part of their graduate-school careers. I want them to find their own niche by the time they are ready to write their Ph.D. dissertations. Being at Harvard, I was blessed with incredibly talented students, and I've learned an enormous amount from them. I've tried to emulate my Ph.D. advisor, Gordon H. Bower, and continue to be a resource for them if they so desire.

If you would not have made it as a scientist, what would you have become? Having spent time in the Silicon Valley ecology now, I'm impressed by the ability of venture capitalists to steer fields and shape developments. They are often a bit like good Program Officers at granting agencies, but more so. Being a venture capitalist looks like it could be a ton of fun — especially if one is oriented toward doing social good, not just making financial returns.

What has been your biggest mistake? I probably spent too much time trying to convince other people that my hypotheses regarding mental imagery were correct. There comes a point when the data have to speak for themselves. If I was correct, others should be able to build on what I did and eventually provide independent support for the ideas. This has now happened with regard to the role of area V1 in visual mental imagery, and the new findings are far more compelling than what my group produced.

Do you feel a push towards more applied science — and if so, how does that affect your own work? As should be evident in the above, I feel a very strong push toward applied science. And this push resulted in my leaving Harvard to go to Stanford to try to change the direction of the Center for Advanced Study in the Behavioral Sciences, and then resigning there to join a startup.

The push toward applied work probably has its roots in my high school experience, which I endured in a suburb of Los Angeles during the 1960s. I was struck by how many of the country's problems hinged on bad thinking and bad behavior by its citizens, and came to believe passionately in the importance of education. But I was sorely disappointed by the education I had received up to that point; too much memorization, too much passive reception, too little thinking and creating (these were familiar complaints then, and are familiar complaints now).

Thus, when I began college at UCLA, I was focused on figuring out how to help people learn to think more clearly and creatively. I began as a philosophy major, believing that philosophy was the appropriate training for the mind. It actually was helpful, but had the regrettable tendency to raise interesting questions, and then to raise more interesting questions. It took me about six months to realize that philosophy (as interesting as it is) wasn't going to answer any questions about how to reform education. Psychology seemed like the answer: I reasoned that understanding the mind should help one figure out how to change it. The problem then became the paucity of information about the mind. At that stage, psychology was just shaking off its behaviorist perspective (my first publication, when I was an undergrad, was a behavioral study with rats). I didn't see any alternatives, and stuck with psychology.

As it developed many years later, turning to studies of the brain opened up an entirely new way to think about education. I was an early adopter of neuroimaging techniques. Some of our studies focused on the nature of individual differences. In particular, we looked at how variations in regional brain activity predicted variations in behavior. Ultimately, my hope was that we could use such results to validate simple behavioral tests, and that those tests in turn could be used to characterize each person's 'processing profile'. This profile would indicate what sorts of processing a given person was good at, and what sorts of processing that person was not so good at. And, knowing this, we could figure out how best to help that person learn. This interest was a facet of my more general interest in the science of learning, which has deep potential applications in all walks of life.

In general, my inclination towards applications has kept me alert to potential ways that basic science can be put into practical contexts, which has proven very useful.

Which aspect of science, your field or in general, would you wish the general public knew more about? I wish the public understood how useful basic research is. I understand the value of 'problem-driven' applied research, but find it often narrow and circumscribed. Basic research provides foundations for solving problems that don't even exist yet. I wish the public could be educated to understand the value — in every sense of the term – of just understanding deeply the nature of our world and ourselves.

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Quick guide

Plant vacuoles

Cornelia Eisenach, Rita Francisco, and Enrico Martinoia

The *plant vacuole, as such, does not exist.* Of course, this is a crude overstatement, but as a matter of fact, the plant vacuole is a versatile organelle that assumes a multitude of functions — depending on cell type, plant organ and developmental stage it can act as the lytic vacuole, as a storage compartment, as a pressure cushion or as a bouquet of flavour and colour (Figure 1).

The plant vacuole — isn't that like the animal lysosome? Of course, one of its most ubiquitous functions is as a recycling machine that contains a large set of hydrolytic enzymes such as acidic phosphatases or proteases. It is also part of the secretory system and communicates with the endomembrane system. Yet, the role of the plant vacuole is much more versatile. In contrast to lysosomes, the size is very different in different cell types and the pH of a plant vacuole can range from neutral, as it is in the beautiful blue morning glory, to far below 3, for instance in lemon or non-ripened grape berries.

Do you have a sweet tooth? If so, you must be a fan of the plant vacuole. The vacuole is the major store for mono-, di-, and oligosaccharides. The vacuoles of sugar beet or sugar cane store sugar in the form of the disaccharide sucrose, at very high concentrations. Although sucrose is a common reserve carbohydrate stored in plant vacuoles, many plants also contain large amounts of glucose and fructose and some species store carbohydrates in the form of fructans. These linear polymers, constituted of fructose linked to sucrose, are produced within the vacuole and if they are small, they taste sweet to us. However, humans do not contain enzymes to break down fructans for energy production, so vacuoles from fructan-producing plants such as chicory or Jerusalem artichoke also help to sweeten coffee for sufferers from diabetes or for the calorie-conscious.

What makes a vegetarian meal protein rich? The plant vacuole! Besides carbohydrates, plant vacuoles store proteins, especially in seeds. Leguminous crops such as lentils, peas and soybeans, as well as cereals such as wheat, rye and barley contain specialised protein storage vacuoles which keep a supply of nitrogen for seed germination. However, not all proteins stored in seeds are edible. The castor oil plant *Ricinus communis*, for example, stores the lectin ricin in its seed protein storage vacuoles. Ricin is lethal since it inhibits eukaryotic protein biosynthesis, even if only a few seeds are consumed.

Where does a wine's bouquet come from? From A to Z a wine's bouquet comes from the plant vacuole. If you like to muse about the elegant, expressive nose of a wine, consider that the components giving taste to wine are stored in the grape berry's vacuole. Glucose and fructose are converted into alcohol, while the main carboxylic acids malic or tartaric acid exhibit a specific taste and give the wine the acidity. The specificity of a wine is given by secondary metabolites stored in the vacuole. Flavonoids such as tannins are not only important for the taste, but also add to the feel and texture (body) of the wine. Finally, other phenolics such as cinnamic acid or terpenoid derivatives contribute to the wine's specific aroma. The low pH observed in grape berries drives the uptake and traps acids by protonation. For wine quality, vacuolar acidity is an important feature, since it balances the alcohol and helps to preserve the wine. Acidification of the vacuole can occur through three different proton pumps. The most important is the V-type H^+-ATPase, which can be found also in fungi and animals. In eukaryotes, H^+-pyrophosphatases are found only in plants, while a P-type H^+-ATPase is found only in specific plant tissues, mainly in cells containing a very acid vacuole like those of fruits and flower petals.

How do plants defend themselves and also human kind? With the help of their vacuoles. As sessile organisms, plants cannot move away when the going (or environment) gets rough around them. Whether it be heavy metals in their soil or salt in their water, plants detoxify harmful compounds such as sodium, arsenic or cadmium